Long-Term Competitiveness:

R&D Policy Issues in a Knowledge-Based Economy

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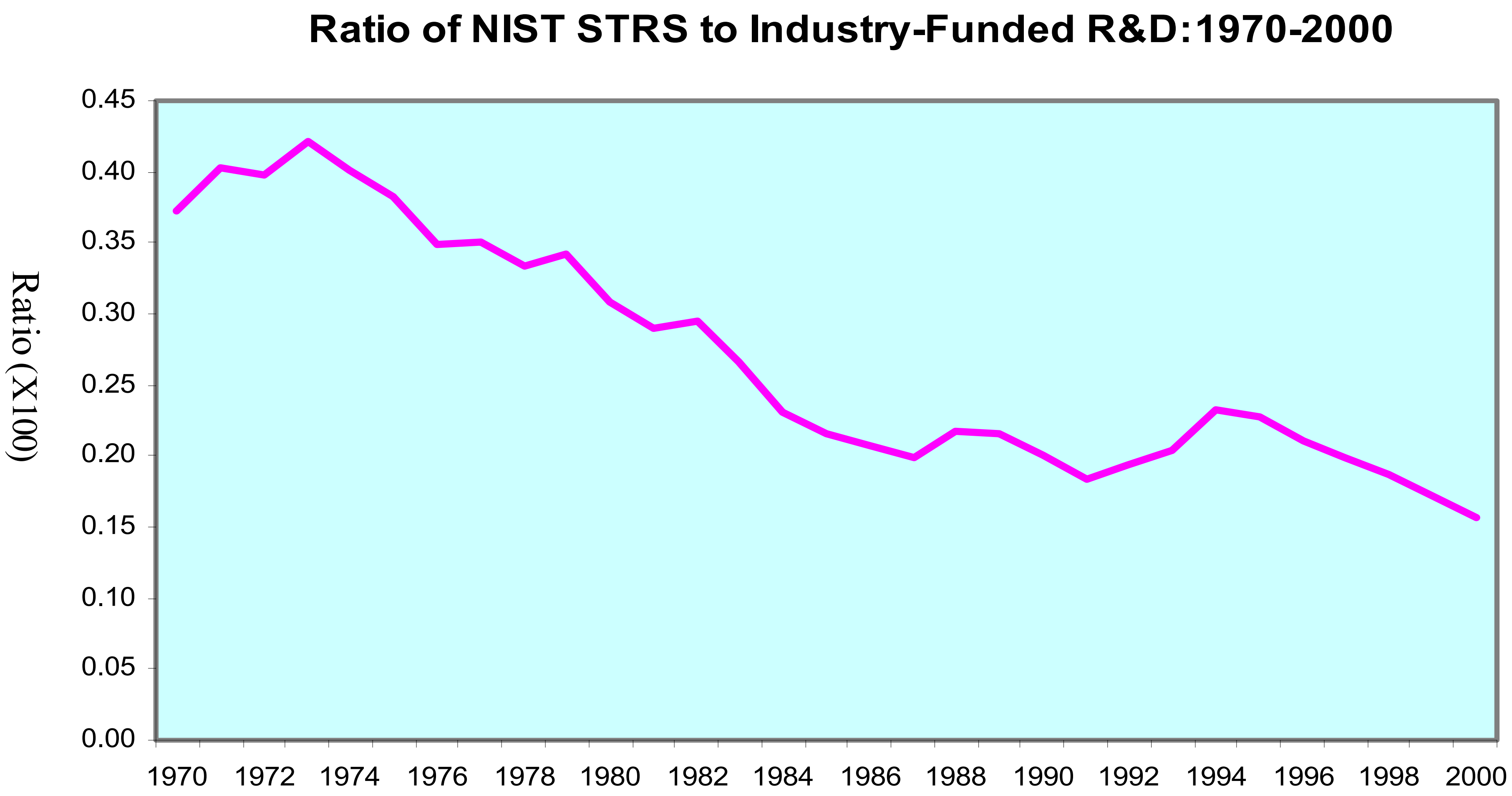
The long run is not a problem—

until you get there

Ratio of NIST Infratechnology Funding to Industry-Funded R&D: 1970-2000



Source: National Science Foundation; NIST Budget Office

R&D Policy

- All advanced economies have an "R&D policy"
- Implies a belief in "market failures"
- Requires large and varied set of indicators
- Requires consensus conceptual framework
- Protracted policy debates

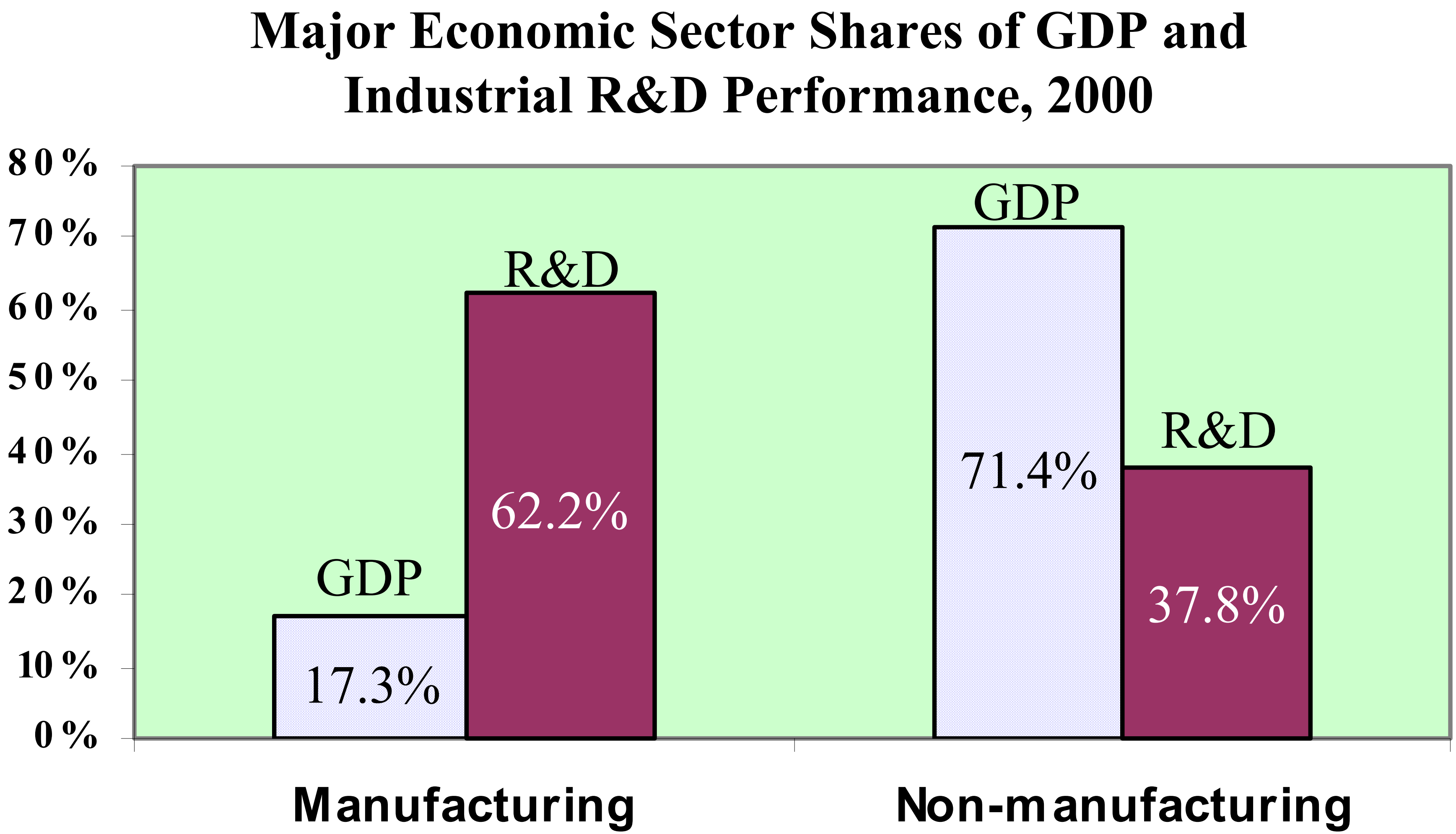
Steps in R&D Policy Analysis:

- **Importance** of technology
- **Indicators** of underinvestment in R&D?
  - Low rates of innovation
  - Low rates of productivity growth
  - Persistent trade balances
- **Causes** of underinvestment (market failure mechanisms)
  - Excessive discounting
  - Appropriability problems
  - Industry or market structure deficiencies
  - Inadequate infrastructure
- **Responses** (policy instruments that match the identified market failures)

How High-Tech is the U.S. Economy?

- **Technology** accounts for more than 50 percent of **output** (GDP) growth in all OECD countries (except Canada)
- Technology (through innovation and capital deepening) accounts for 2/3 of **productivity** growth
- **Message:** R&D is a **critical policy variable** because it is the process that creates technology

How High-Tech is the U.S. Economy?

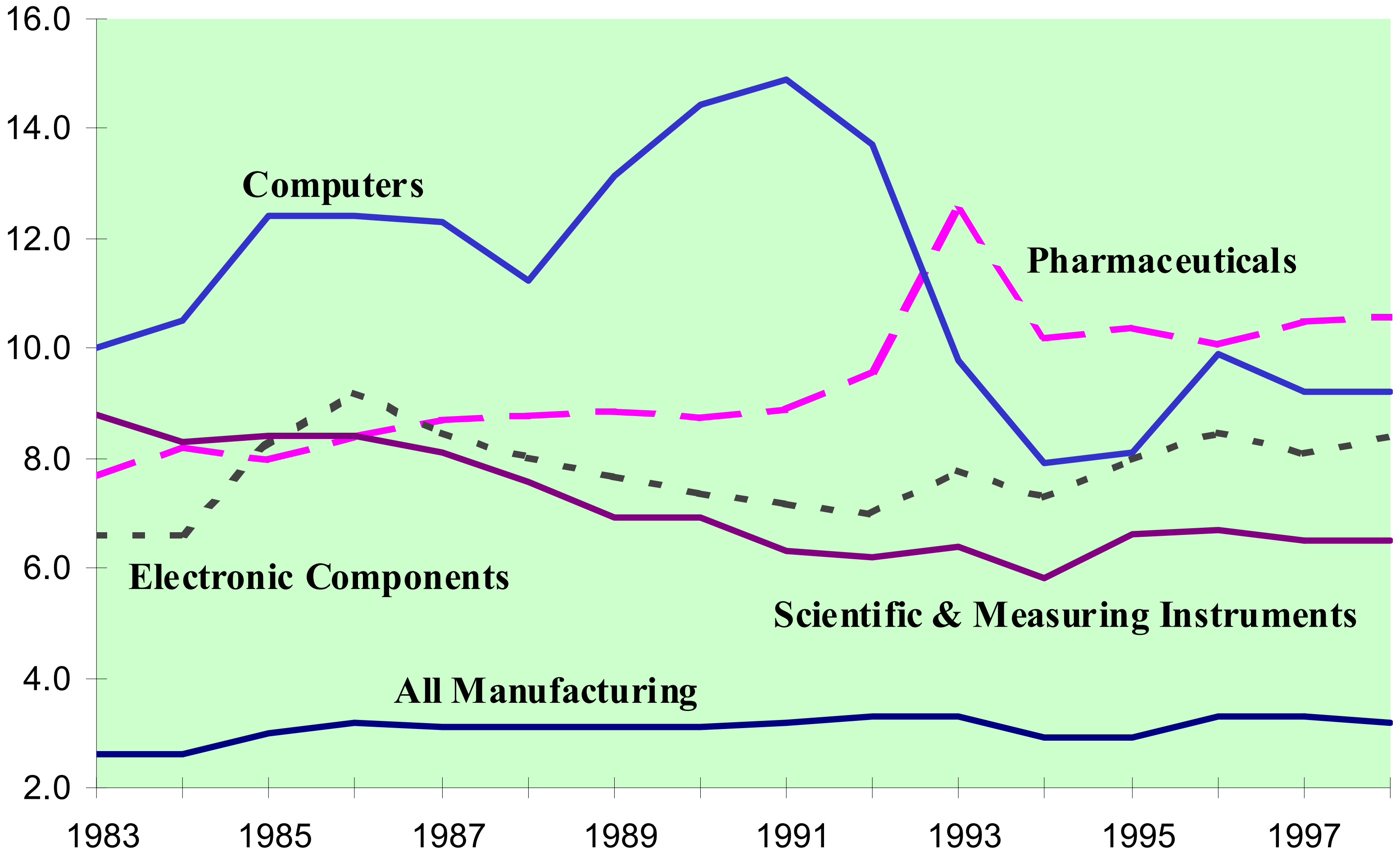


Source: Bureau of Economic Analysis; National Science Foundation, *Research and Development in Industry–2000,* Table E-1

How High-Tech is the U.S. Economy?

R&D-to-Sales Trends in Manufacturing: 1983-1998

Company and Other (except Federal) R&D Funds as % of Net Sales



Source: National Science Foundation, *National Patterns of R&D Resources*: *Early Release Tables, 2000*

How High-Tech is the U.S. Economy?

- **High-Tech Sector:**
  - Electronics
  - Pharmaceuticals
  - Communication Services
  - Software and Computer-Related Services
- **Accounts for 7 – 10 percent of GDP**
- **Message:** The other 90+ percent of the economy is susceptible to market share erosion and decline

How High-Tech is the U.S. Economy?

Geographic Concentration:

- Six states account for almost one-half of all R&D
- Ten states account for almost two-thirds of all R&D
- **Message:** The remaining 40 states are not a high-tech economy

How High-Tech is the U.S. Economy?

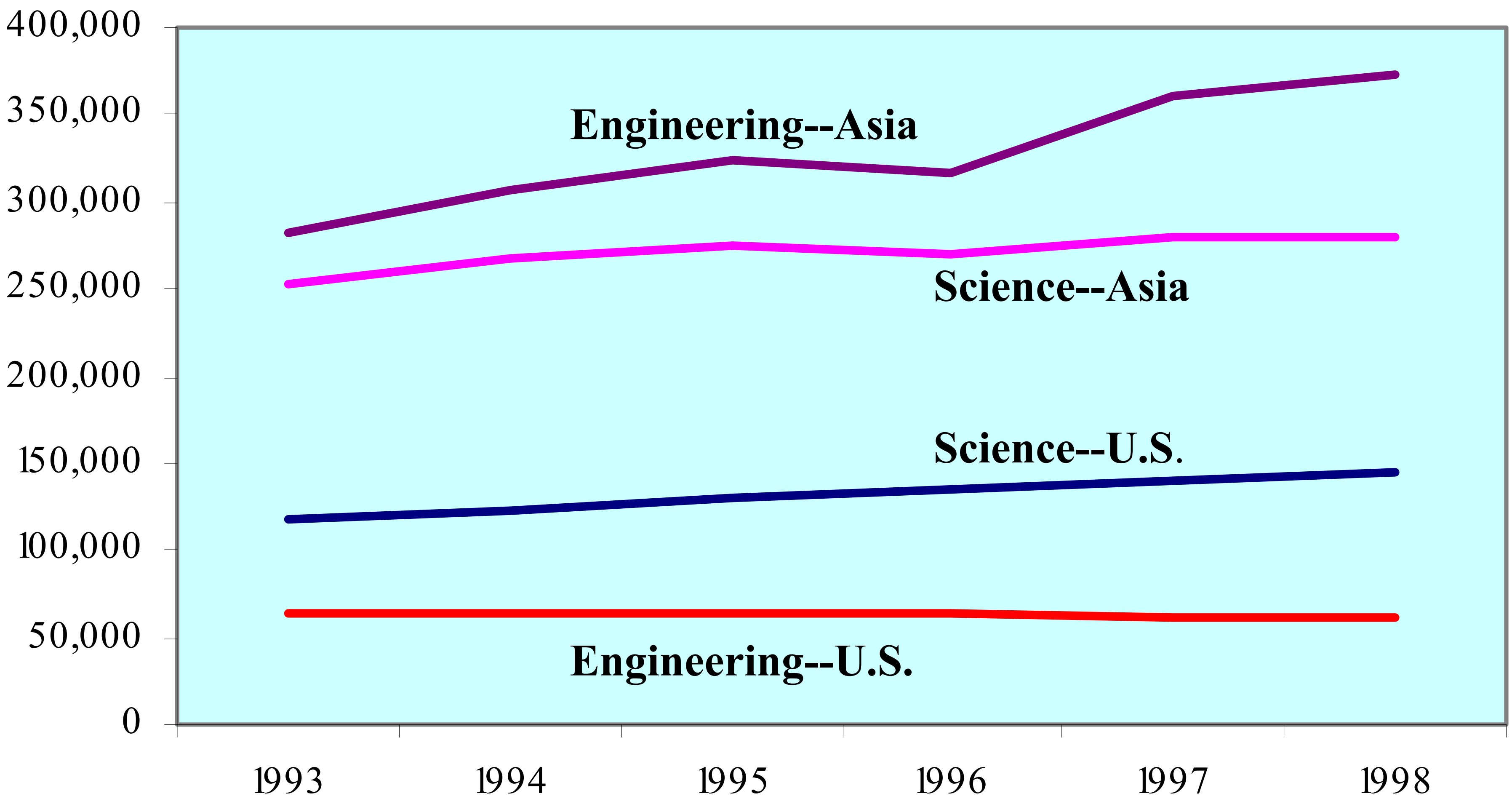
Geographic Distribution of U.S. R&D Performance

State	% of Population	% of National R&D
California	12.0	20.7
Michigan	3.5	8.1
New York	6.7	6.1
Texas	7.4	5.4
Massachusetts	2.3	5.3
Pennsylvania	4.4	4.6
New Jersey	3.0	4.6
Illinois	4.4	4.2
Washington	2.1	3.6
Maryland	1.9	3.5
Total	**47.7**	**66.1**

Source: National Science Foundation

How High-Tech is the U.S. Economy?

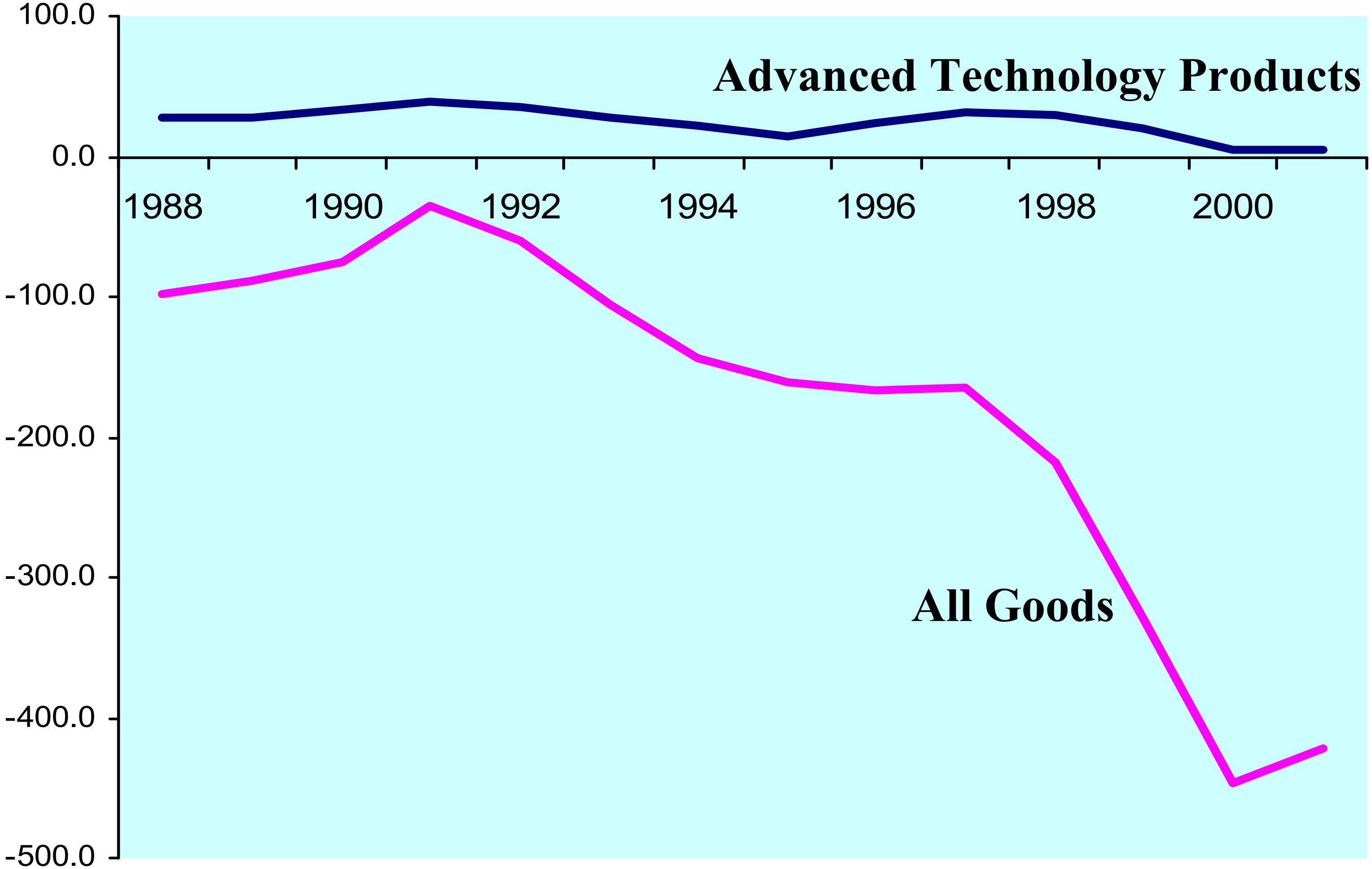
Bachelor's S&E Degrees in the United States and Asia: 1993-1998



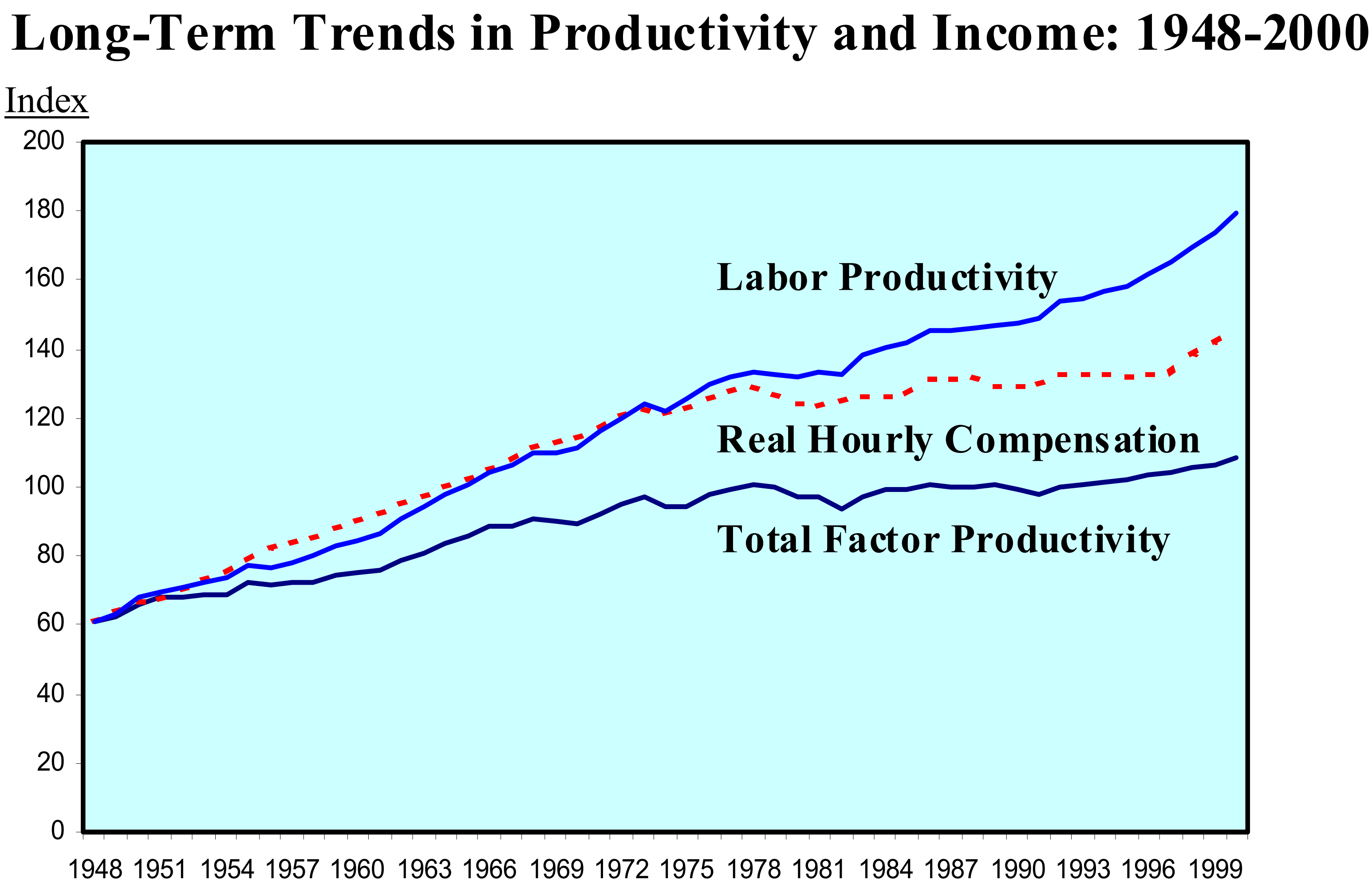
Source: National Science Foundation, S&EI, Appendix Table 2-33. Asian data include China, India, Japan, South Korea, and Taiwan

How Has the "High-Tech" Economy Performed?

U.S. Trade Balances for High-Tech Products and All Goods 1988-2001 (in $billions)



How Has the “High-Tech” Economy Performed?



Source: Bureau of Labor Statistics

How Has the "High-Tech" Economy Performed?

Razor's Edge Growth Path:

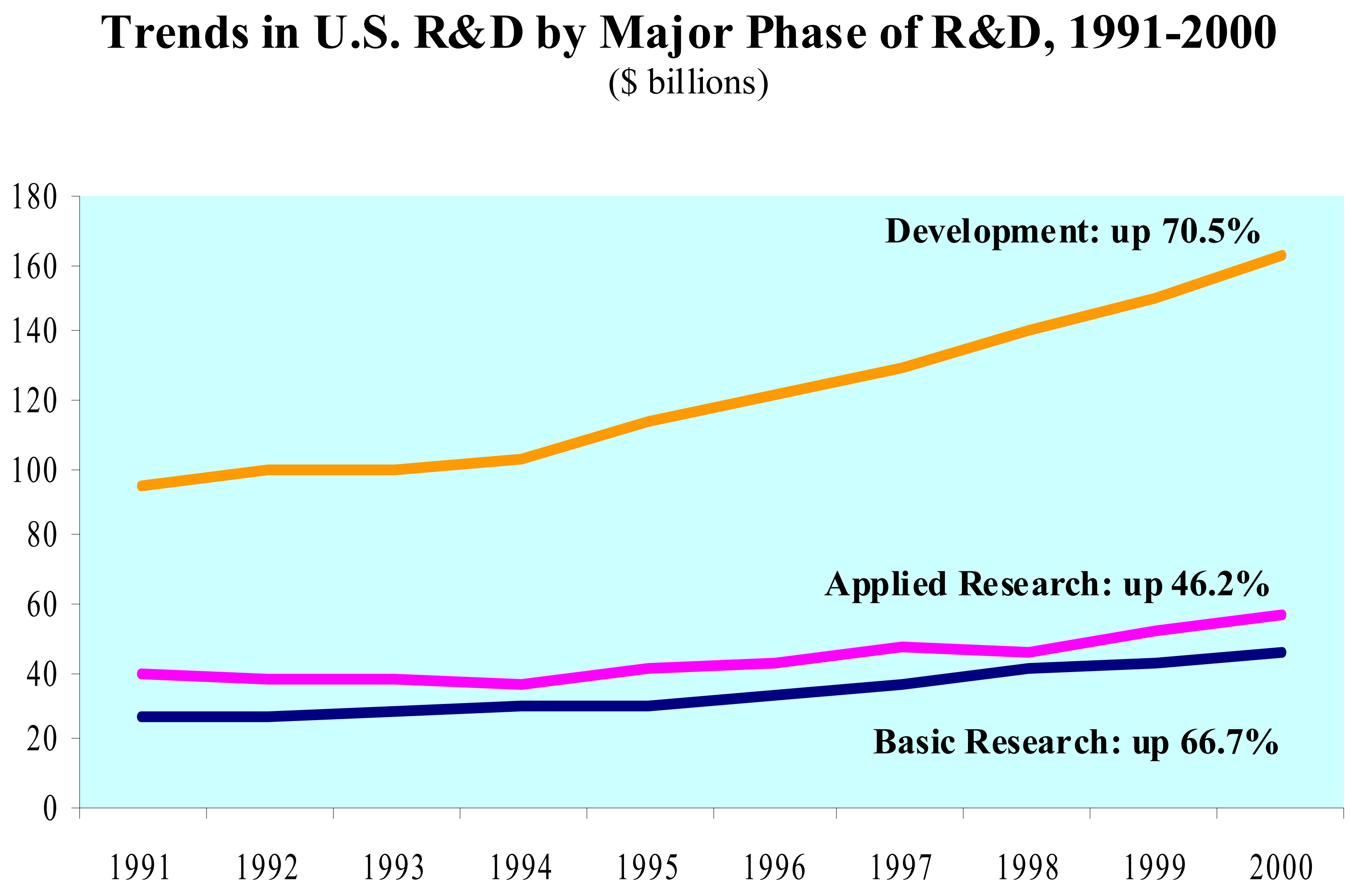
- TFP growth highly dependent on 12% of the economy producing durable goods, notably computers (Gordon)
- IT products responsible for above trend growth in late 1990s (Oliner and Sichel)
- Sharp reduction in TFP would result if semiconductor industry product life cycle returns to 3 years from recent 2 years (Jorgenson)
- **Message:** Prospects for above-trend long-term productivity growth are poor

How Important is the Composition of R&D?

The "New Economy":

- IT (or ICT) has infrastructure character
- Need **products** and **services** from a broader high-tech sector
    - Source: IT systems based on a range of innovative products from the manufacturing sector
    - Synergy: Productivity of manufacturing benefits from IT services
    - Impact: The manufacturing sector accounts for $1.5 trillion of GDP and 20 million jobs
- **Message:** advanced economies need a broad and deep R&D strategy, including a manufacturing focus

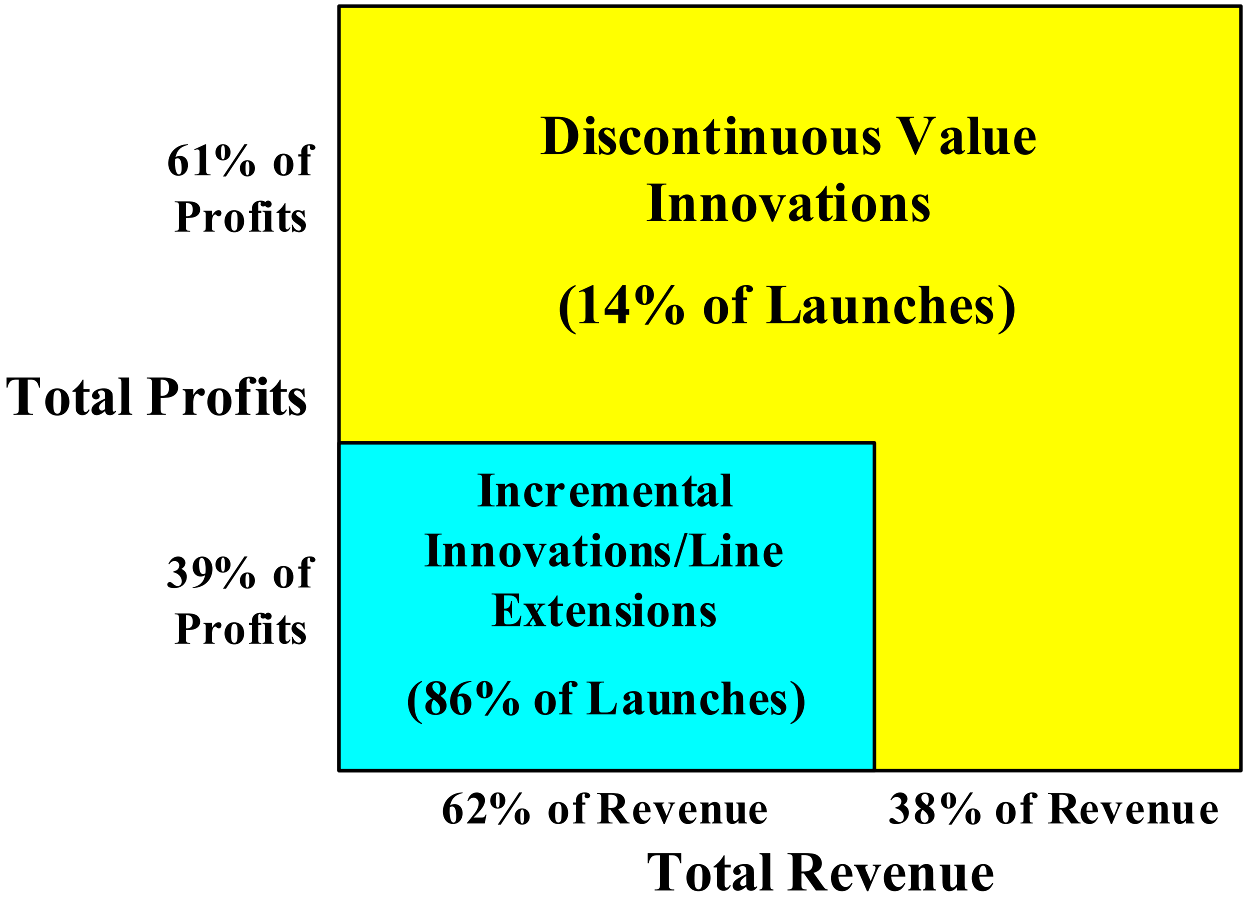
How Important is the Composition of R&D?



Source: National Science Foundation, *National Patterns of R&D Resources*: *Early Release Tables, 2000*

How Important is the Composition of R&D?

Profit Differentials for Major & Incremental Innovations



Source: W. Chan Kim and Renée Mauborgne, "Value Innovation: The Strategic Logic of High Growth", *Harvard Business Review* 75:1(1997)

How Important is the Composition of R&D?

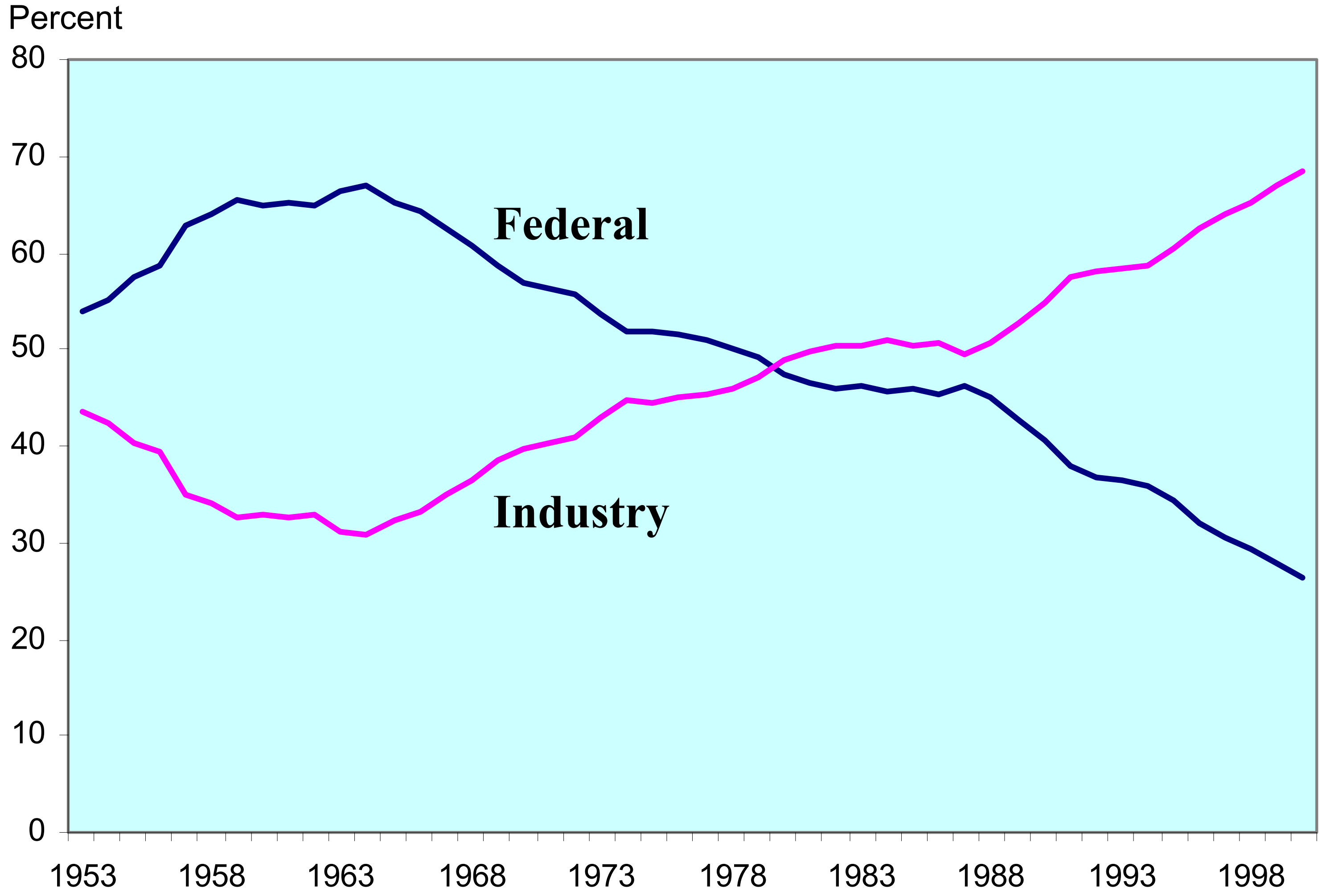
IRI "Sea Change" Index:
Member Firms' Annual Planned Investments in Directed Basic Research

Year	Percent Planning Increase (> 5%)	Percent Planning Decrease	Sea Change Index
1993	14	40	-26
1994	13	39	-26
1995	8	27	-19
1996	17	23	-6
1997	15	41	-26
1998	14	28	-14
1999	14	37	-23
2000	17	26	-9
2001	17	38	-21
2002	12	25	-13

Source: Industrial Research Institute

How Important is the Composition of R&D?

Federal and Industry Shares of US R&D Expenditures, 1953–2000

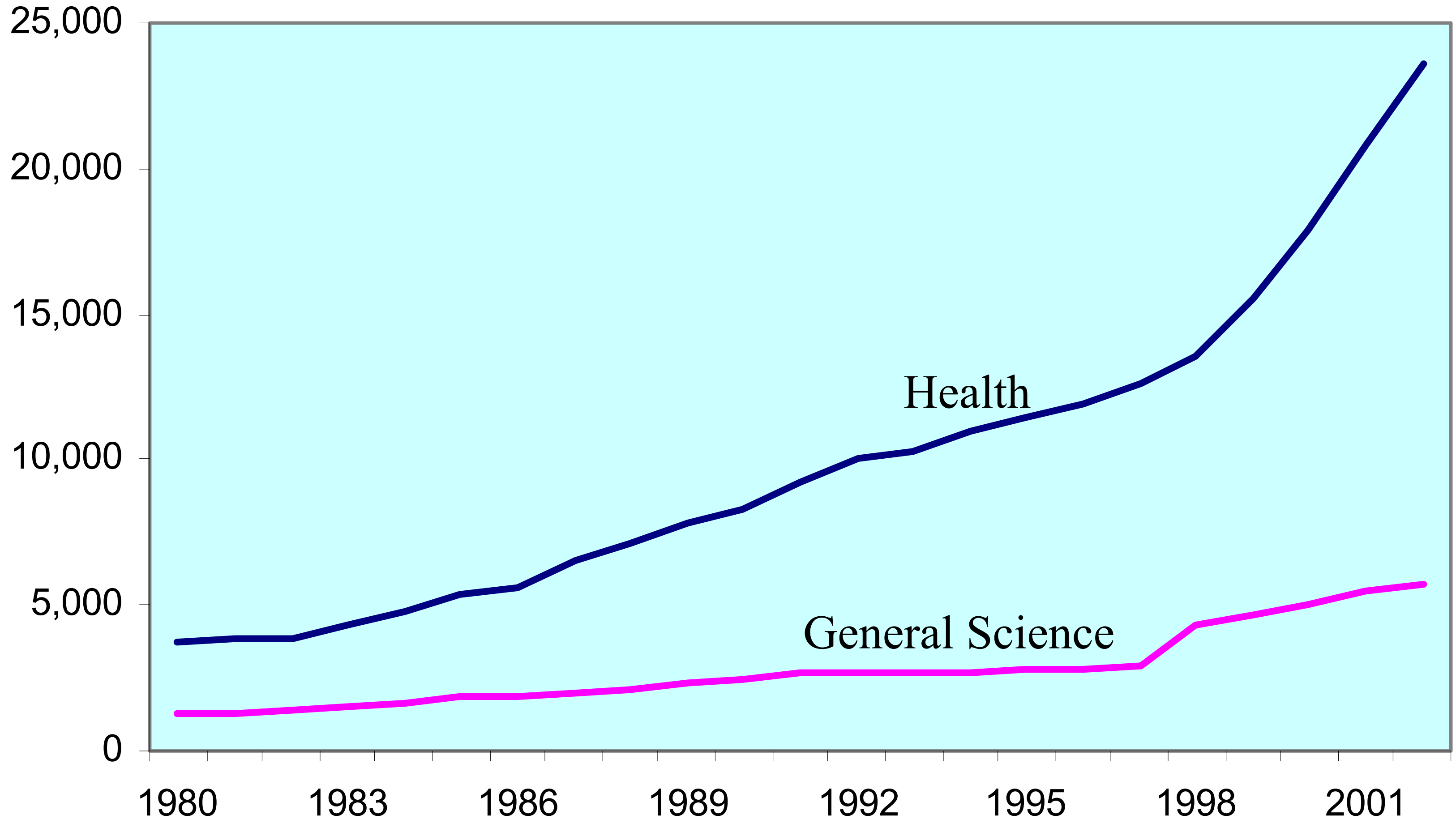


Source: National Science Board, *Science and Engineering Indicators – 2002*, Appendix Table 4-5

How Important is the Composition of R&D?

Federal R&D for Health and General Science, FY 1980-2002

(budget authority in millions of dollars)



Source: National Science Board, *Science and Engineering Indicators* – 2002

R&D Market Failure Mechanisms

Implications for Adequacy of R&D Investment:

- Inadequate **amount**
- Skewed **composition** of industrial R&D toward short-term investment objectives
- **Geographic concentration**
- **Skewed distribution** of federal R&D across emerging technologies

Message: the long run is here

R&D Market Failure Mechanisms

(1) ***Technical Complexity***

(2) ***Time***

(3) ***Capital Intensity***

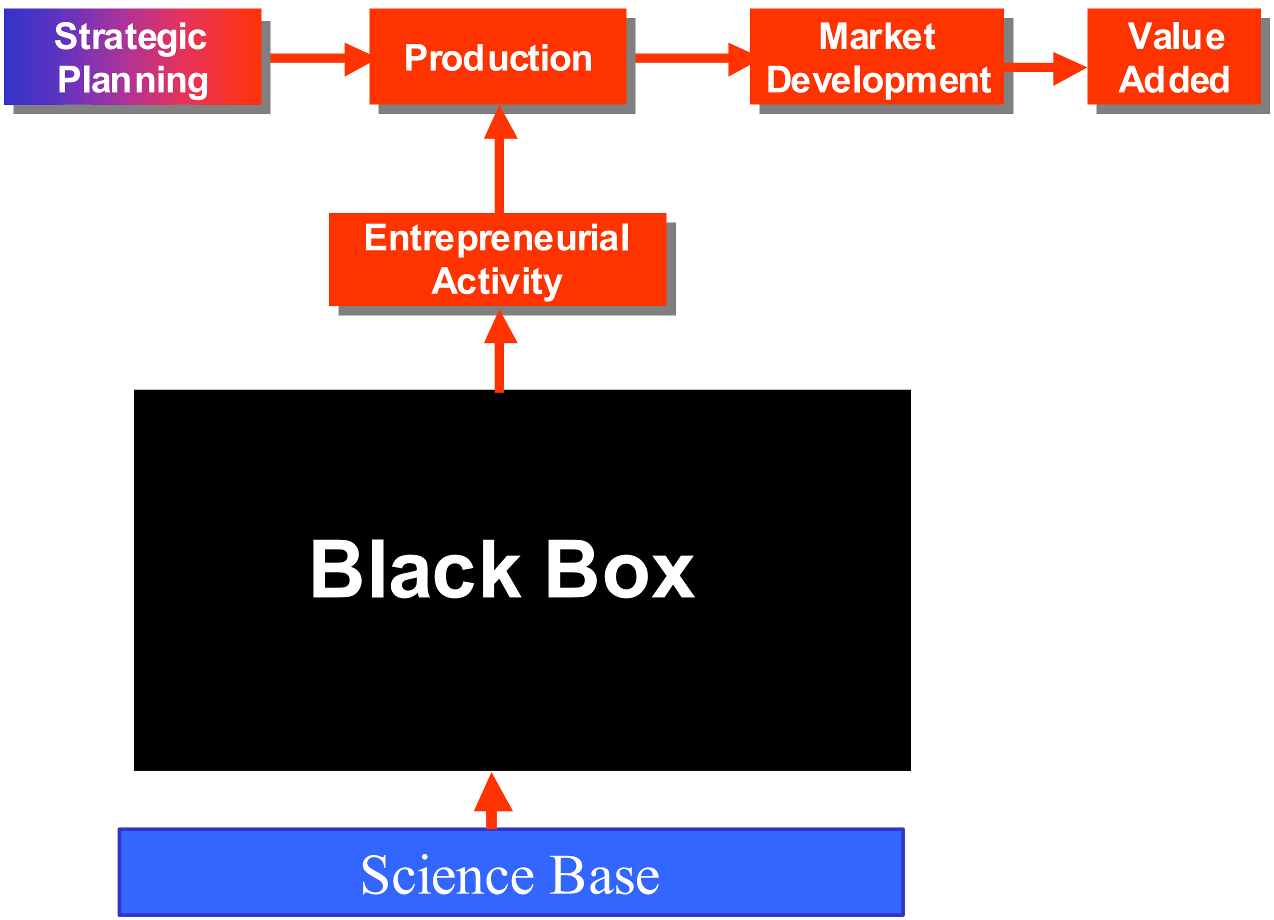
(4) ***Economies of Scope***

(5) ***Spillovers***

(6) ***Technical Infrastructure***

R&D Market Failure Mechanisms

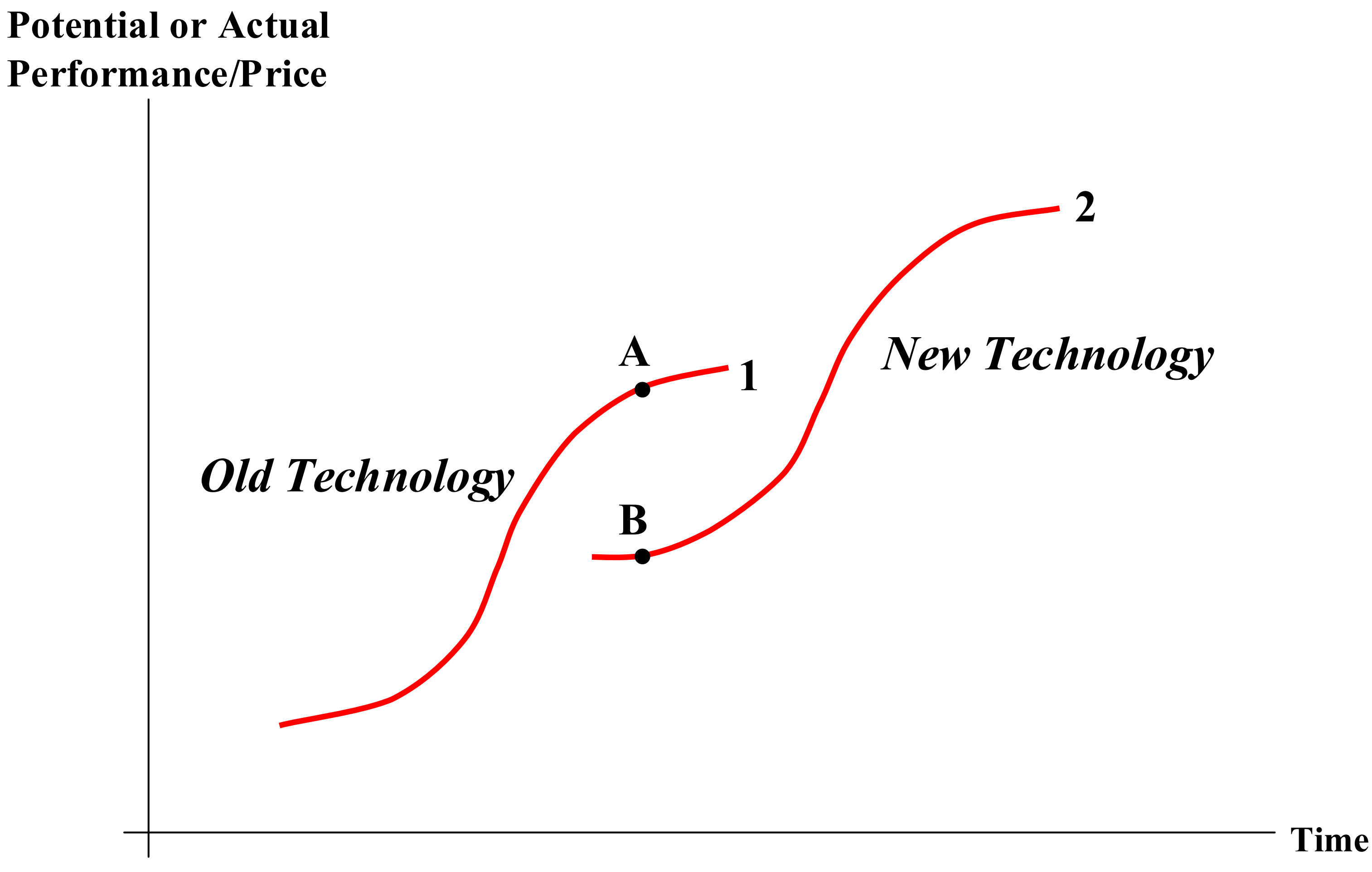
"Black Box" Model of a Technology-Based Industry



Source: G. Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, p. 70

R&D Market Failure Mechanisms

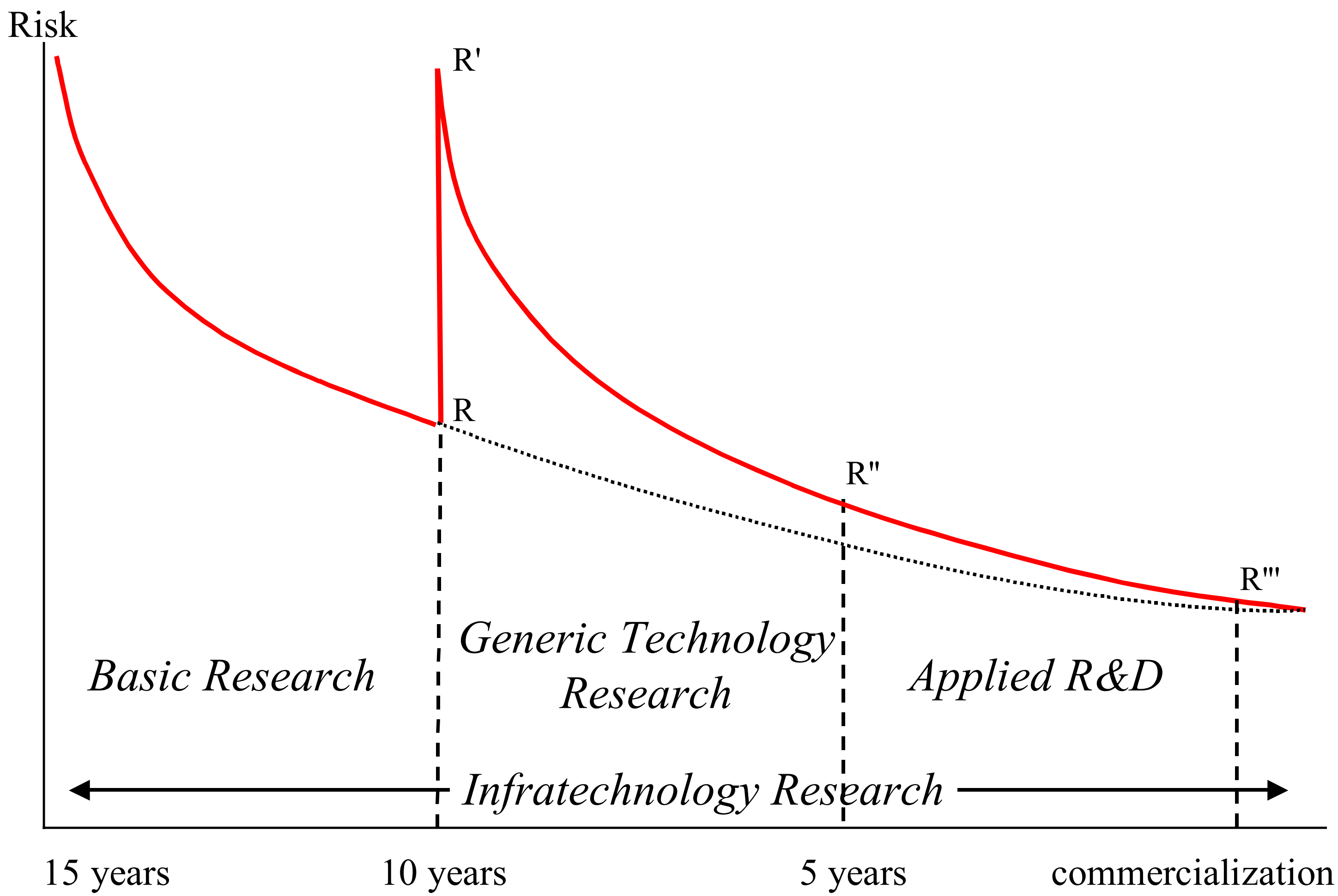
Transition Between Two Technology Life Cycles



Source: Gregory Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, Chap. 7

R&D Market Failure Mechanisms

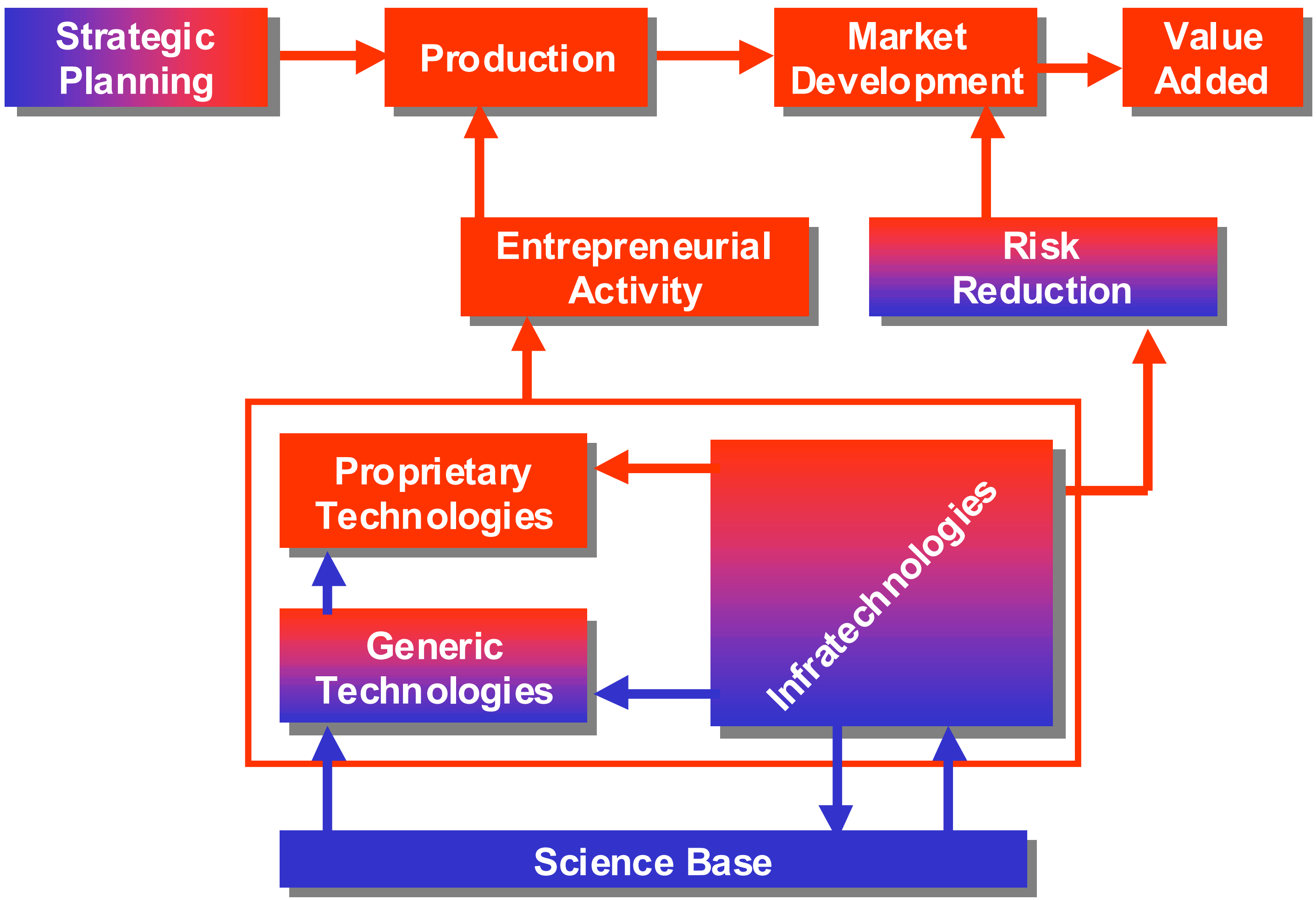
Risk Reduction Over a Technology Life Cycle



Source: Gregory Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, Chap. 7

R&D Market Failure Mechanisms

Economic Model of a Technology-Based Industry



Source: G. Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, p. 70

R&D Market Failure Mechanisms

Interdependency of Public–Private Technology Assets: Biotechnology

Science Base

- Genomics
- Immunology
- Microbiology/ virology
- Molecular and cellular biology
- Nanoscience
- Neuroscience
- Pharmacology
- Physiology
- Proteomics

Infratechnologies

- bioinformatics
- biospectroscopy
- combinatorial chemistry
- DNA chemistry, sequencing, and profiling
- Electrophoresis
- Fluorescence
- gene expression analysis
- magnetic resonance spectrometry
- mass spectrometry
- nucleic acid diagnostics
- protein structure modeling/analysis techniques

Generic Technologies

Product

- antiangiogenesis
- antisense
- apoptosis
- bioelectronics
- biomaterials
- biosensors
- functional genomics
- gene delivery systems
- gene testing
- gene therapy
- gene expression systems
- monoclonal antibodies
- pharmacogenomics
- stem-cell
- tissue engineering

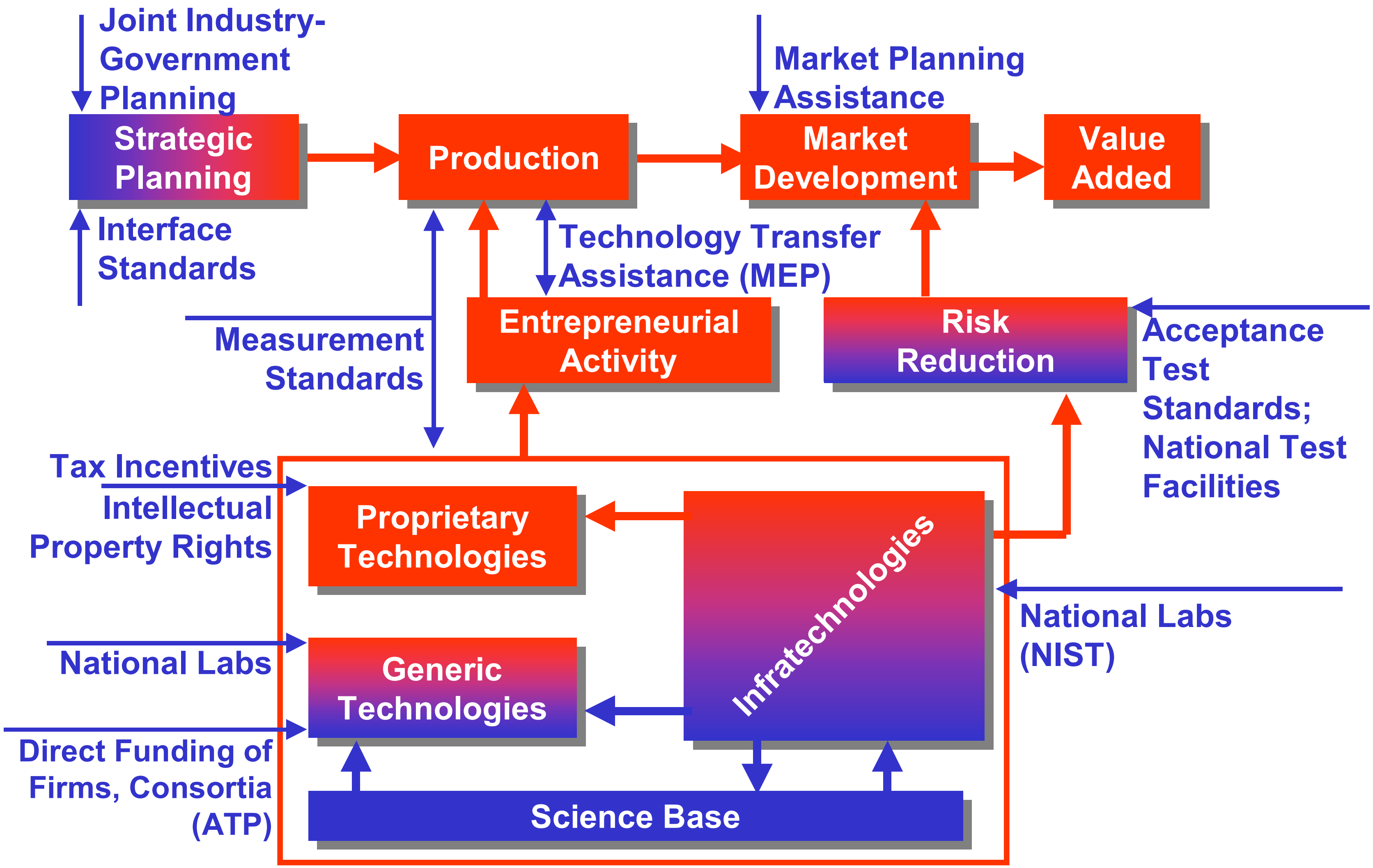
Process

- cell encapsulation
- cell culture
- DNA arrays/chips
- fermentation
- gene transfer
- immunoassays
- implantable delivery systems
- nucleic acid amplification
- recombinant DNA/genetic engineering
- separation technologies
- transgenic animals

Commercial Products

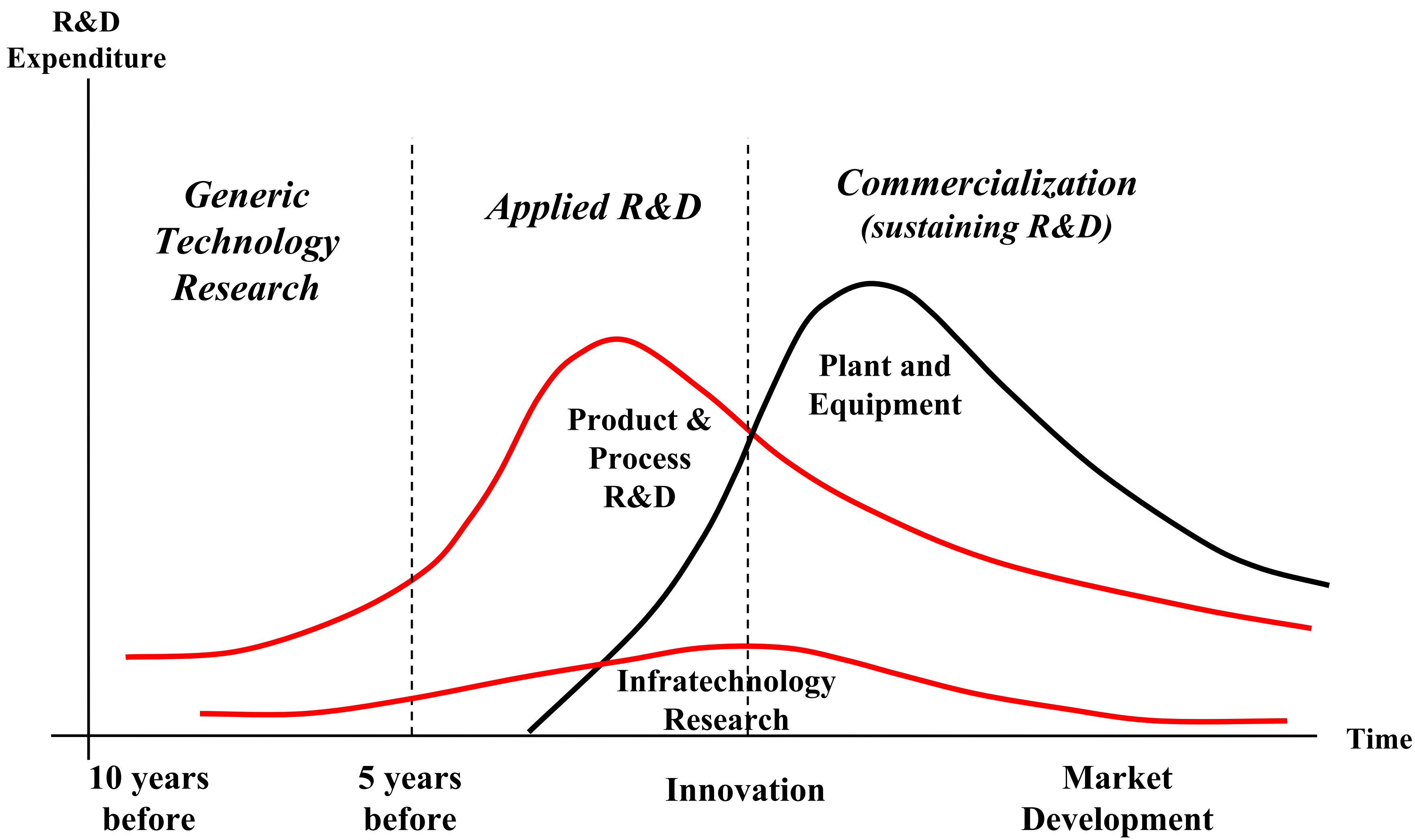
- coagulation inhibitors
- DNA probes
- inflammation inhibitors
- hormone restorations
- nanodevices
- neuroactive steroids
- neuro-transmitter inhibitors
- protease inhibitors
- vaccines

Technology-Based Policy Responses



Technology-Based Policy Responses

Relative Expenditures by Phase of R&D over Technology Life Cycle



Source: Gregory Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, p. 74

Technology-Based Policy Responses

Critical Government Research Support Provided for Major Technology Drivers:

- Computers (Flamm)
- Communications Networks (NRC)
- Biotechnology
- Nanotechnology
- **Message:** Once identified, major emerging technologies must be disaggregated to identify public good leverage points

Technology-Based Policy Responses

What type of R&D?

Costs of Inadequate Software Testing Infrastructure

Industry Coverage	Annual Cost	Potential Economic Benefits
Transportation Equipment and Financial Services	$5.85 B	$2.10 B
U.S. Economy	$59.5 B	$22.2 B

Source: RTI International, *The Economic Impacts of Inadequate Infrastructure for Software Testing* (NIST Planning Report 02-3)

R&D Policy Options

How much R&D?

- If all manufacturing industries invested at the same rate as the high-tech segment, this sector's R&D would increase from $130B to roughly $400B
- If the Federal Government spent as much on all areas of science combined as it does just on health research, its R&D budget would increase by roughly $11B
- One recent economic study (Jones and Williams) estimated that national R&D should be increased by a factor of four

R&D Policy Options

If problem is

- Inadequate **science base**:
  - *fund basic research* at adequate scope and depth
- Inadequate **amount of R&D**:
  - *provide tax incentives* (e.g., R&E tax credit) to raise expected rates of return above corporate hurdle rates
- Distorted **composition of R&D**:
  - *Co-fund generic technology research* to create attractive corporate option pricing for portfolio of emerging technologies